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Comparison of Results from the EDYS and EDYS-L Ecological Simulation Models as Applied to Vegetation and Hydrological Dynamics on the Honey Creek Watershed, Texas

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INTRODUCTION: EDYS (Ecological DYnamics Simulation Model) is a general ecosystem simulation model that is mechanistically based and spatially explicit (Childress and McLendon 1999; Childress et al. 1999, 2002). The model simulates natural and anthropogenic-induced changes in plant, soil, animal, and watershed components across landscapes, at spatial scales ranging from 1 m^2 or less to landscape levels (10^3 km and larger). It is a dynamic model that simulates changes on a daily basis over periods ranging from months to centuries. EDYS has also been linked with groundwater (MODFLOW) and surface runoff (GSSHA, CASC2D, HSPF) models to provide integrated watershed management simulation systems.

EDYS has been applied in ecological evaluations, land management decision making, environmental planning, revegetation and restoration design analysis, and watershed management for federal and state agencies, municipal and water authorities, and corporations at 35 sites in 12 states and in Australia and Indonesia. It has been used in regulatory compliance (U.S. Air Force Academy (USAFA) 2000; Amerikanuak 2006) and is included as part of the U.S. Army Corps of Engineers System-Wide Water Resources Research Program (SWWRP) as a primary terrestrial model (Johnson and Coldren 2006; Johnson and Gerald 2006). EDYS has been widely reviewed scientifically, and its results have been published in over 40 scientific and technical publications and presented at 30 scientific meetings. Validation studies conducted with the U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), Strategic Environmental Research and Development Program (SERDP), and CSIRO-Australia showed EDYS to be 90-95 percent accurate in simulating vegetation dynamics (McLendon and Coldren 2001; McLendon et al. 2001; Hunter et al. 2004; Mata-Gonzalez et al. 2007, 2008) and simulations of evapotranspiration (ET) and runoff that were not statistically different from recorded values at a gauged watershed (McLendon and Coldren 2005). CSIRO-Australia conducted an independent validation test in Queensland and reported that "EDYS was capable of simulating basic ecosystem dynamics in these savanna environments. When run for 50 years using the historical climate record from Charters Towers the model realistically simulated the inter-annual variability in the tree, shrub, and herbaceous layers (Ash and Walker 1999)."

These results demonstrate EDYS to be an accurate and very robust model for use in a very wide range of ecological and environmental applications. However, EDYS is a complex and very sophisticated simulation model that requires considerable training for its successful use. Consequently, the USACE is interested in the development of a second model that can be used in conjunction with EDYS, but that requires less training and is applicable throughout the United States with a minimal amount of data input by the user. The concept is that the second, less sophisticated, model would be used as a screening-level model in applications where lower levels of accuracy are acceptable. In cases where greater accuracy is required, the full EDYS model would be used.

In response to this interest, the developers of EDYS, funded by the USACE, created the EDYS-L model. This simulation model is based on EDYS and retains most of the ecological concepts and algorithms of EDYS, but with simplified plant and soil options. Whereas an application of EDYS might include data for 20-40 plant species for a single watershed, EDYS-L contains data for only 15-20 representative species types for an entire region of the United States. In its initial prototype form, EDYS-L has been parameterized for three regions of the United States: the Southwest, the Central Plains, and the Great Basin. To cover the entire United States, five additional regions will need to be added: Southeast, Northeast, Midwest, Alaska, and Pacific.

The three-region prototype of EDYS-L was demonstrated in a workshop held in Austin, Texas in August 2007 and attended by representatives of USACE, the U.S. Fish and Wildlife Service, and the Texas Parks and Wildlife Department. This EDYS-L prototype proved the concept of a simplified EDYS model. The next step in the developmental process was to determine how much predictive accuracy EDYS-L retains, compared to the full EDYS model. The developers conducted paired simulations of EDYS and EDYS-L for the same modeled watershed and compared the output of the two models. The purpose of this report is to present the results of this comparison.

METHODS: The Honey Creek Research Watershed in Comal County and near San Antonio, Texas was selected as the site for the comparison of the two models. The area is located on the southeastern edge of the Edwards Plateau, an area of limestone hills with abundant karst features. The vegetation is predominately juniper-oak woodland, with openings dominated by midgrasses on moderate-depth soils and shortgrasses on shallow soils. The study area consists of about 540 acres divided into two approximately equal areas (sub-watersheds). Juniper was removed by mechanical means on one sub-watershed beginning in 2003. The second sub-watershed remained untreated and serves as a control. Both sub-watersheds have meteorological stations located in them and a gauge to measure total runoff on the lower portion of the major drainage within each.

EDYS was applied to the Honey Creek watershed in a validation study to determine the ability of the model to simulate ET and runoff dynamics, the results of which indicated that EDYS was highly accurate in simulating these hydrological outputs (McLendon and Coldren 2005). A number of previous studies had shown EDYS to be highly accurate in simulating the dynamics of vegetation similar to that of the Honey Creek watershed (McLendon et al. 2001) and vegetation dynamics in other arid and semi-arid ecosystems (Ash and Walker 1999; McLendon and Coldren 2001; Hunter et al. 2004; Mata-Gonzalez et al. 2007, 2008).

The control sub-watershed was used in the comparison of EDYS and EDYS-L. The sub-watershed was divided into 5-m × 5-m cells and each cell was assigned an elevation, aspect, soil, and vegetation type in EDYS (McLendon and Coldren 2005). The EDYS application used 14 vegetation and surface-feature types (Table 1) and 32 plant species (Table 2). Site-specific daily precipitation data were used, supplied by the USGS. Two-year simulations were run. Output from these EDYS simulations were used as the baseline data to which the corresponding EDYS-L outputs were compared.

Table 1. Vegetation and surface-feature types used in the EDYS and EDYS-L Simulations 1 and 2, Honey Creek Research Watershed, Texas.[1]

EDYS Simulation	EDYS-L1 Simulation	EDYS-L2 Simulation
Juniper-oak (75% / 25%)	Plains montane	Plains montane
Juniper-oak (60% / 10%)	Plains montane	Plains montane
Juniper-oak (50% / 15%)	Plains montane	Plains montane
Oak-juniper (50% / 40%)	Plains montane	Plains montane
Oak-juniper (40% / 30%)	Plains montane	Plains montane
Mixed woodland (50%)	Plains montane	Southwest riparian
Shrub-grassland	Plains montane	Southwest lowland
Bluestem-grama (12%)	Plains montane	Plains lowland
Bluestem-grama (5%)	Plains montane	Plains lowland
Bluestem-prairie (5%)	Plains montane	Plains lowland
Shortgrass	Plains montane	Southwest upland
Rocky slopes	Plains montane	Rocky slopes
Water	Plains montane	Water
Roads	Plains montane	Roads

[1] Percentages following bluestem communities refer to amount of tree cover.

Table 2. Plant species included in the EDYS application for the Honey Creek Research Watershed, Texas.

Trees	Shrubs	Grasses	Forbs
hackberry Texas persimmon Ashe juniper Shumard oak live oak cedar elm mesquite	sotol sumac greenbriar mountain grape prickly pear	purple threeawn KR bluestem silver bluestem sideoats grama hairy grama Texas cupgrass seep muhly little bluestem indiangrass tall dropseed Texas wintergrass curly mesquite	broomweed woodland sedge doveweed rabbit tobacco prairie bluet prairie coneflower Texas sage orange zexmenia

The purpose of this comparison was to quantify how similar (i.e., how accurate) the results of EDYS-L were to those of EDYS. To do so, four EDYS-L simulations were run. In the first simulation, only one EDYS-L community was included (Table 1). This simulation represented the coarsest scale available in EDYS-L, and corresponds to the scale requiring the least ecological knowledge and training on the part of the user. The second EDYS-L simulation utilized all plant communities in EDYS-L that were appropriate for the site. There were five such communities plus three surface-feature types (Table 1). This level of application is at a more complex scale than the first EDYS-L simulation and requires more ecological knowledge of the site than required by the first simulation. The communities and species used in an EDYS-L application are composites of the region-wide generic communities and species that represent community- and species types as opposed to site specific. For example, ponderosa pine and big sagebrush are not found in the Edwards Plateau of Texas (Table 3). They are used in EDYS-L to represent all coniferous trees and all upland shrubs, respectively, in the Central Plains. For the Honey Creek

EDYS-L application, the Plains Montane type was the most similar EDYS-L lifeform equivalent to the Ashe juniper communities that are found in the Edward Plateau.

Table 3. Initial aboveground biomass values (total for trees, clippable for others; g/m^2) for species included in the EDYS-L vegetation types applied in Simulations 1 and 2 for the Honey Creek Research Watershed, Texas.

Species	Plains Montane	Plains Lowland	Southwest Riparian	Southwest Lowland	Southwest Upland
ponderosa pine	11,624	0	0	0	0
cottonwood	0	0	19,001	0	0
mesquite	0	0	0	806	21
big sagebrush	243	0	8	0	0
creosotebush	0	0	0	0	36
coyote willow	1	0	2	0	0
blue grama	52	4	7	0	43
bermudagrass	0	45	7	35	0
saltgrass	1	1	18	25	1
little bluestem	3	170	2	0	1
alkali sacaton	3	53	8	336	6
smooth cordgrass	4	0	7	0	0
Baltic rush	0	0	12	23	0
ragweed	12	23	16	0	3
tansymustard	4	3	3	3	1
sunflower	4	15	11	3	1
sweetclover	2	5	0	25	0
Russian thistle	1	3	8	4	1

The third EDYS-L simulation was the same as the second except that two additional plant species were added to EDYS-L: Ashe juniper (*Juniperus ashei*) and live oak (*Quercus virginiana*). These are the two dominant woody species at the site. The purpose of adding these two species was to evaluate the importance of having the dominant species included in EDYS-L, rather than simply using the most similar lifeform equivalent. In this simulation, Ashe juniper replaced ponderosa pine as the coniferous tree (Table 4). This replacement made it possible to determine whether or not the accuracy of EDYS-L was improved when the dominant species were included instead of just community type. The fourth EDYS-L simulation was similar to the third simulation except that various levels of juniper and oak cover densities were included (Table 5). Tree biomass values used in EDYS-L Simulations 3 and 4 (Tables 4 and 5) were based on data used in the EDYS simulations for Cibolo Creek (Price et al. 2004) and Honey Creek (McLendon and Coldren 2005) watersheds. All EDYS-L simulations were run using the same spatial footprint and precipitation data as were used in the EDYS simulation.

Table 4. Ashe juniper (JUAS), live oak (QUVI), ponderosa pine (PIPO), and cottonwood (POFR) initial total aboveground biomass (g/m2) levels used in the EDYS-L communities in Simulation 3 for the Honey Creek Research Watershed, Texas.

EDYS-L Community	JUAS	QUVI	PIPO	POFR	Tree Cover
Plains montane	5928	3255	0	0	79%
Southwest riparian	950	4275	0	4275	50%
Plains lowland	539	296	0	0	7%

Table 5. Ashe juniper (JUAS), live oak (QUVI), ponderosa pine (PIPO), and cottonwood (POFR) initial total aboveground biomass (g/m^2) levels used in the EDYS-L communities in Simulation 4 for the Honey Creek Research Watershed, Texas.

EDYS Community	EDYS-L Community	JUAS	QUVI	PIPO	POFR
Juniper-oak (75% / 25%)	Plains montane 75-25	8718	2096	0	0
Juniper-oak (60% / 10%)	Plains montane 60-10	6974	1162	0	0
Juniper-oak (50% / 15%)	Plains montane 50-15	5812	1743	0	0
Oak-juniper (50% / 40%)	Plains montane 50-40	4648	5812	0	0
Oak-juniper (40% / 30%)	Plains montane 40-30	3486	4648	0	0
Mixed woodland (50%)	Southwest riparian	950	4275	0	4275
Bluestem-grama (12%)	Plains lowland (12%)	697	697	0	0
Bluestem-grama (5%)	Plains lowland (5%)	291	291	0	0
Bluestem-prairie (5%)	Plains lowland (5%)	291	291	0	0

Six endpoint variables were used to evaluate the accuracy of EDYS-L versus EDYS. There were two hydrological variables: ET (inches) and runoff (inches). ET and runoff were calculated as monthly means averaged over the entire watershed. There were four vegetation variables: total woody aboveground biomass, total juniper aboveground biomass, total live oak aboveground biomass, and total herbaceous aboveground biomass. All vegetation variables were annual end-of-growing season (October) means, averaged over the entire sub-watershed.

RESULTS AND DISCUSSION

Vegetation. From the numerous ecological variables that could be used to compare the results of the two models, a sub-set of five was chosen. The first variable is total aboveground biomass. This is a very broad vegetation variable, but one that captures the basic overall vegetation dynamic of the watershed. Overall, is the vegetation increasing or decreasing and by how much? The second and third variables are similar to the first, but compare the two major plant lifeforms at the site, trees and herbaceous species. The fourth and fifth variables look at changes in the dominant species of trees.

Three metrics were calculated for all five variables. The first was the ratio of the EDYS-L value for that variable at the end of the second year of the simulation to the corresponding EDYS value. The second metric was a similarity index (EDYS Similarity Index = ESI), which is a measurement of the accuracy of EDYS-L compared to EDYS simulations (i.e., the smaller of the two values divided by the larger). The third metric is a measure of vegetation change, calculated as the value in the second year divided by the initial value. A value of 1.00 indicates no change over the two years. A value less than 1.00 indicates that this variable declined and a value greater than 1.00 indicates that it increased. These vegetation change ratios can then be compared between models to determine how similar the two models are in projecting vegetation dynamics in the watershed.

When comparing overall aboveground biomass, EDYS-L had an ESI of 69 percent when applied at its coarsest level (i.e., one community type applied across the entire landscape; EDYS-L1, Table 6). This very coarse scale would be applied if the user had no knowledge of compositional and spatial heterogeneity of the landscape. The only requirements on the part of the user would be to know which geographical region the landscape was located in (Southwest, Central Plains, or Great Basin) and which of the five topographic categories (montane, upland, lowland, riparian, wetland) was most characteristic of the landscape. Assuming that EDYS simulations are 90-95 percent accurate, EDYS-L at this very coarse scale produced a 60-65 percent solution [(90-95%) (69%) = 62-66%] for the Honey Creek watershed.

The ESI of EDYS-L was substantially improved when multiple EDYS-L community types were applied to the Honey Creek watershed (EDYS-L2, Table 6). This EDYS-L scenario requires that the user apply the most applicable EDYS-L community type (out of a current total of 15) to each spatial unit identified on the landscape. The spatial units might be identified by remote sensing, ground mapping, GIS-based elevational or soil groupings, or some other means. At this level of EDYS-L application and using five EDYS-L community types and three surface-feature types (Table 1), EDYS-L produced results within 93 percent of those produced by EDYS. This equates to an 80-90 percent solution, assuming a 90-95 percent accuracy for EDYS.

Further refinement of the spatial and compositional resolution of EDYS-L did not result in an increase in ESI (Table 6). Adding the two dominants (EDYS-L3, Table 6) and greater spatial heterogeneity (EDYS-L4, Table 6) resulted in a decrease in ESI. This decrease was the result of the initial biomass values (3934 and 3715 g/m^2, Table 6) being lower than the corresponding value in the EDYS simulation (4606 g/m^2). Although initial biomass values were lower in both of these EDYS-L scenarios, total biomass was converging toward the EDYS value. Therefore, the lower ESI was not the result of the EDYS-L model being less accurate under these two scenarios, but it was the result of the lower initial values. The model was performing as would be expected given the lower initial values. Total biomass was increasing toward the higher value under EDYS. In contrast, under the first two EDYS-L scenarios in which initial biomass values were higher than the EDYS value (Table 6), total biomass decreased over the two years. Again, EDYS-L was producing values that were converging toward the EDYS value.

Table 6. Simulated total aboveground biomass (g/m²) averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

Year	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
0	4606	6587	4817	3934	3715
1	4447	6415	4714	3905	3689
2	4414	6427	4768	3986	3781
Yr2/EDYS Yr2	1.00	1.46	1.08	0.90	0.86
ESI[1]	1.00	0.69	0.93	0.90	0.86
Year 2/Year 0	0.96	0.98	0.99	1.01	1.02

[1] ESI = EDYS Similarity Index = smaller of (EDYS sum or EDYS-L sum) divided by larger of the two.

The results for tree biomass (Table 7) were very similar to those for total biomass (Table 6), in large part because most of the biomass on this watershed is contained in trees. The relationship between EDYS-L and EDYS results for herbaceous biomass followed the same pattern as for total biomass but the ESI values were lower (Table 8). Using EDYS, herbaceous biomass in the second year was the same as it was initially. In the first EDYS-L scenario (EDYS-L1), herbaceous biomass was lower in the second year, probably because of the relatively high tree biomass values out-competing the grasses and forbs (Table 7). Tree biomass was much lower in the other three EDYS-L scenarios and herbaceous biomass increased. These are very reasonable ecological responses to competition between trees and understory species. The higher second-year values in these three EDYS-L scenarios, and therefore the relatively low ESI values of about 40 percent, were primarily the result of the higher initial herbaceous biomass values.

Table 7. Simulated total aboveground biomass (g/m²) of trees averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

Year	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
0	4546	6518	4703	3820	3601
1	4403	6396	4615	3807	3600
2	4354	6404	4621	3833	3628
Yr2/EDYS Yr2	1.00	1.47	1.06	0.88	0.83
ESI[1]	1.00	0.68	0.94	0.88	0.83
Year 2/Year 0	0.96	0.98	0.98	1.00	1.01

[1] ESI = EDYS Similarity Index = smaller of (EDYS sum or EDYS-L sum) divided by larger of the two.

Table 8. Simulated aboveground clippable biomass (g/m2) of herbaceous species averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

Year	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
0	36.2	41.6	68.7	68.7	68.7
1	26.3	11.2	59.4	58.5	54.3
2	36.1	14.0	88.4	91.9	91.6
Yr2/EDYS Yr2	1.00	0.39	2.45	2.55	2.54
ESI[1]	1.00	0.39	0.41	0.39	0.39
Year 2/Year 0	1.00	0.34	1.20	1.34	1.33

[1] ESI = EDYS Similarity Index = smaller of (EDYS sum or EDYS-L sum) divided by larger of the two.

Two of the EDYS-L scenarios (EDYS-L3 and EDYS-L4, Table 9) included the two site-dominants, Ashe juniper (JUAS) and live oak (QUVI). In both cases, the EDYS-L results were similar to the EDYS results for Ashe juniper (94 percent and 87 percent, respectively; Table 9), although juniper biomass increased slightly in both EDYS-L cases and decreased in EDYS. EDYS-L simulation results for live oak were less similar to those of EDYS than were the results for juniper. Although the similarities were lower, the EDYS-L results for live oak were still 60-80 percent solutions (assuming a 90-95 percent accuracy for EDYS).

Table 9. Simulated total aboveground biomass (g/m^2) of Ashe juniper (JUAS) and live oak (QUVI) averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and two variations of the EDYS-L model.

Year	JUAS			QUVI		
	EDYS	EDYS-L3	EDYS-L4	EDYS	EDYS-L3	EDYS-L4
0	2393	2382	1953	1867	1308	1518
1	2300	2378	1956	1820	1281	1492
2	2272	2410	1983	1799	1267	1480
ESI[1]	1.00	0.94	0.87	1.00	0.70	0.82
Yr2/Yr0	0.95	1.01	1.02	0.96	0.97	0.97
JUAS/QUVI[2]	1.26	1.90	1.34			

[1] ESI = EDYS Similarity Index = smaller of (EDYS sum or EDYS-L sum) divided by larger of the two.
[2] JUAS/QUVI = Year 2 JUAS value divided by Year 2 QUVI value.

The EDYS simulations indicated that Ashe juniper had 26 percent more biomass than live oak by the second year (Table 9). The EDYS-L4 simulation produced similar results (34 percent). However the results of the EDYS-L3 were not as close: there was a higher ratio of juniper to live oak (1.9:1). This is most likely because of a lower initial biomass value for live oak. Live oak biomass declined over the two simulation years in all three cases (EDYS, EDYS-L3, EDYS-L4), indicating that both models were producing the same pattern for live oak dynamics.

Evapotranspiration (ET). EDYS-L produced ET patterns similar to those produced by EDYS, i.e., when ET increased in EDYS, ET increased in EDYS-L and when ET decreased in EDYS, ET decreased in EDYS-L (Table 10). Although the patterns were similar, EDYS-L simulations resulted in higher ET values than those simulated in EDYS. EDYS simulations resulted in an average annual ET for Honey Creek of about 25 in. (Table 10). The average annual value reported by the USGS from their Honey Creek MET stations was 25.5 in. (McLendon and Coldren 2005). Values reported in the literature for the Edwards Plateau range from 17.5-19.0 in. for juniper communities (Dugas et al. 1997, Wu et al. 2001) and 17.3-20.1 in. for juniper-oak communities (Jackson et al. 1999). Reported rates for mesquite communities are 13.0-34.7 in. in South Texas (Weltz and Blackburn 1995) and 25.3 in. in North Texas (Carlson et al. 1990).

The simulated ET rates for the first two EDYS-L scenarios were more than twice the EDYS values (Table 10). ET values were not as great in the third and fourth EDYS-L scenarios, although they were still substantially higher than the EDYS and the USGS values. These high ET values may have been the result of the thicker soil profiles used in EDYS-L, which initially contained more soil water than was in the actual profiles of the shallow Honey Creek soils. Even with the high ET values, EDYS-L had an ESI of 42-66 percent, depending on which scenario was used (Table 10).

Runoff. The runoff values simulated by EDYS-L were very low compared to those simulated by EDYS (Table 11). This was, in part, because of the high ET values simulated in EDYS-L and the relatively high amount of herbaceous biomass in EDYS-L. High ET values tend to deplete soil moisture, especially in the upper soil layers. This allows more water from storm events to enter the upper soil layers, thereby reducing runoff. High herbaceous biomass, an artifact of the input data in EDYS-L, reduces runoff by reducing the velocity of the water flowing across the landscape surface. As the flow rate is reduced, more water can enter the profile, thereby reducing runoff.

Although the runoff amounts simulated by EDYS-L were low, the patterns were consistent with EDYS runoff patterns (Table 11). The amount of runoff in EDYS-L also increased as the composition and spatial heterogeneity became more similar to those in EDYS. Runoff in the simplest EDYS-L version averaged 1.7 in. Runoff in the most complex EDYS-L version averaged 2.4 in.

Similarity of EDYS-L to EDYS Results over a 10-Year Simulation. EDYS-L results appeared to be converging toward EDYS results after the second year of the simulation (Tables 6-11). To determine if this convergence would continue over a longer period of time, 10-year simulations were run. These simulations indicated that the convergence of EDYS-L results toward EDYS results did continue in some cases but not in others. For total aboveground biomass, the ESI decreased for the two EDYS-L scenarios where juniper and live oak were not included (EDYS-L1 and EDYS-L2) but increased where they were included (EDYS-L3 and EDYS-L4, Table 12). This suggests that output from the more simple EDYS-L versions may become less similar to that from EDYS over time. The EDYS-L1 version had a 69 percent ESI after two years but a 65 percent ESI after 10 years (Table 12), and EDYS-L2 had a 93 percent ESI after two years and an 88 percent ESI after 10 years. Conversely, ESI increased over time for EDYS-L3 and EDYS-L4. After two years, ESI values were 90 percent and 86 percent, respectively, and after 10 years, they were 99.6 percent and 94 percent, respectively (Table 12).

Table 10. Simulated monthly ET values (inches) for the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

Month	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
01	2.30	5.52	4.05	4.54	4.03
02	1.02	2.60	2.00	1.54	1.93
03	2.76	4.98	3.86	3.42	3.26
04	1.55	4.48	3.78	3.14	2.91
05	3.28	6.62	6.14	5.23	4.73
06	1.32	2.02	2.20	2.64	2.75
07	0.19	1.20	0.97	0.98	0.99
08	3.30	10.66	9.07	5.39	5.02
09	2.50	2.99	2.92	4.02	3.93
10	2.35	5.71	5.09	3.73	3.45
11	1.94	5.84	4.41	2.09	1.96
12	1.69	4.15	3.18	1.89	1.69
13	1.93	3.02	2.37	3.81	3.20
14	0.91	1.81	1.66	1.36	1.83
15	1.68	3.40	2.90	2.08	1.94
16	1.75	2.61	2.78	2.95	2.77
17	2.06	3.57	3.49	3.34	3.27
18	1.69	4.85	4.13	2.94	2.78
19	3.89	17.95	16.01	7.83	7.31
20	2.01	2.19	1.99	3.25	3.20
21	2.65	4.88	4.49	4.27	4.22
22	3.40	9.39	7.94	4.87	4.64
23	1.59	4.18	3.29	1.85	1.71
24	1.80	4.23	3.30	2.09	1.88
Sum	49.56	118.85	102.02	79.25	75.40
Annual	24.78	59.43	51.01	39.63	37.70
Sum/EDYS	1.00	2.40	2.06	1.60	1.52
ESI[1]	1.00	0.42	0.49	0.63	0.66

[1] ESI = EDYS Similarity Index = EDYS Sum/EDYS-L Sum.

Table 11. Simulated total annual runoff (inches) from the control sub-watershed of the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

Year	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
1	6.71	1.51	1.83	2.07	2.13
2	9.45	1.83	2.38	2.51	2.60
Sum	16.16	3.34	4.21	4.58	4.73
Mean	8.08	1.67	2.11	2.29	2.37
Sum/EDYS	1.00	0.21	0.26	0.28	0.29

Table 12. Simulated total aboveground biomass (g/m2) after 2 years and 10 years, averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Year 2					
Aboveground biomass	4414	6427	4768	3986	3781
EDYS Similarity Index[1]	1.00	0.69	0.93	0.90	0.86
Year 10					
Aboveground biomass	4247	6576	4824	4263	4067
EDYS Similarity Index[1]	1.00	0.65	0.88	1.00	0.96

[1] EDYS Similarity Index (ESI) = smaller of (EDYS biomass or EDYS-L biomass) divided by larger of the two.

The similarity between EDYS-L and EDYS hydrologic results decreased over time. ET was about 30 percent less similar between the models after 10 years than it was after 2 years (Table 13) and runoff was 5-10 percent less similar (Table 14).

Table 13. Simulated evapotranspiration (inches) after 2 years and 10 years, averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Year 2					
Evapotranspiration	25.36	62.08	54.33	40.64	38.74
EDYS Similarity Index[1]	1.00	0.41	0.47	0.62	0.65
Year 10					
Evapotranspiration	16.75	60.02	52.03	39.24	39.36
EDYS Similarity Index[1]	1.00	0.28	0.32	0.43	0.43

[1] EDYS Similarity Index (ESI) = smaller of (EDYS ET or EDYS-L ET) divided by larger of the two.

Table 14. Simulated runoff (inches) after 2 years and 10 years, from the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Year 2					
Runoff	9.45	1.83	2.38	2.51	2.60
EDYS Similarity Index[1]	1.00	0.19	0.25	0.27	0.28
Year 10					
Runoff	10.60	1.92	2.46	2.72	2.72
EDYS Similarity Index[1]	1.00	0.18	0.23	0.26	0.26

[1] EDYS Similarity Index (ESI) = smaller of (EDYS runoff or EDYS-L runoff) divided by larger of the two.

Effect of Adjusting Initial Biomass Values. One potential source of inaccuracy in EDYS-L is associated with the initial biomass values that are part of the input data. The biomass values that are included in each community type in EDYS-L are averages for the community type over an entire region. For example, the tree biomass value for the Plains Montane type (Table 3) is an average for a moderate stand of ponderosa pine in the eastern foothills of central Colorado. When applied to the Honey Creek watershed in Texas, the value is 43 percent greater than the tree biomass at Honey Creek (Table 7). This is one of the major trade-offs in a screening-level model. In its most coarse scale of application (one community type, EDYS-L1), EDYS-L can be applied with no external vegetation data inputs. This provides great utility for inexperienced users. But it comes with a reduced level of realism and accuracy.

To test the sensitivity of EDYS-L to initial biomass values, all four EDYS-L scenarios were re-run with adjusted initial biomass values. In each of the four scenarios, the initial biomass values were set to equal the total aboveground biomass values used in EDYS. Biomass allocation percentages remained the same for each species as they were in the first runs with EDYS-L, but the total biomass amounts were adjusted to match those in EDYS.

All four of the EDYS-L scenarios produced results very similar (ESI = 95-97 percent) to those produced by EDYS for total aboveground biomass when the input for initial total aboveground biomass was standardized between the two models (Table 15). However, adjusting the initial biomass had little impact on hydrologic output (Tables 16 and 17).

Table 15. Simulated total aboveground biomass (g/m2) after two years with and without standardized initial (Year 0) biomass values, averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Different Initial Biomass					
Aboveground biomass	4414	6427	4768	3986	3781
EDYS Similarity Index[1]	1.00	0.69	0.93	0.90	0.86
Same Initial Biomass					
Aboveground biomass	4414	4667	4568	4606	4590
EDYS Similarity Index[1]	1.00	0.95	0.97	0.96	0.96

[1] EDYS Similarity Index (ESI) = smaller of (EDYS biomass or EDYS-L biomass) divided by larger of the two.

Table 16. Simulated evapotranspiration (inches) after two years with and without standardized initial (Year 0) biomass values, averaged over the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Different Initial Biomass					
Evapotranspiration	25.36	62.08	54.33	40.64	38.74
EDYS Similarity Index[1]	1.00	0.41	0.47	0.62	0.65
Same Initial Biomass					
Evapotranspiration	25.36	60.11	53.48	42.42	39.84
EDYS Similarity Index[1]	1.00	0.42	0.47	0.60	0.64

[1] EDYS Similarity Index (ESI) = smaller of (EDYS ET or EDYS-L ET) divided by larger of the two.

Table 17. Simulated runoff (inches) after two years with and without standardized initial (Year 0) biomass values, from the control sub-watershed at the Honey Creek Research Watershed, Texas, using EDYS and four variations of the EDYS-L model.

	EDYS	EDYS-L1	EDYS-L2	EDYS-L3	EDYS-L4
Different Initial Biomass					
Runoff	9.45	1.83	2.38	2.51	2.60
EDYS Similarity Index[1]	1.00	0.19	0.25	0.27	0.28
Same Initial Biomass					
Runoff	9.45	1.96	2.40	2.49	2.60
EDYS Similarity Index[1]	1.00	0.21	0.26	0.26	0.28

[1] EDYS Similarity Index (ESI) = smaller of (EDYS runoff or EDYS-L runoff) divided by larger of the two.

CONCLUSIONS

Vegetation Dynamics. EDYS-L proved to be a useful screening-level ecological model when applied to the Honey Creek Research Watershed in Texas, especially for simulating changes in vegetation. When compared to the EDYS model, EDYS-L produced second-year simulated results for total aboveground biomass that had an ESI (EDYS Similarity Index) of 69 percent, when applied at the coarsest EDYS-L scale. This coarse scale corresponded to the application of one EDYS-L plant community-type to the entire Honey Creek landscape. This would be the scale that could be used with a minimum of ecological knowledge of the site. The user would only need to know which geographical region the site was in and which of five topographic types was most common at the site. When multiple EDYS-L community types were applied to the landscape, the ESI value increased to 93 percent. The ESI was not improved by the addition of the two site-dominants to the EDYS-L suite of species, but when these two species were added EDYS-L produced simulation results that had ESI values of 87-94 percent for Ashe juniper and 70-82 percent for live oak. EDYS-L was therefore capable of providing very reasonable simulation results for both overall biomass and compositional changes among the major species.

One estimate of simulation accuracy (i.e., the accuracy of the simulated results compared to measured results) is the product of the ESI and the accuracy of EDYS. This is a conservative measure because by multiplying the two factors it assumes that the combined error is cumulative when in fact it may not be. For example, if the EDYS value for a particular variable is low and the EDYS-L value is greater than the EDYS value, then the EDYS-L value would be closer to the measured value than what would be indicated by the product of the EDYS accuracy and the ESI. However, this ESI product approach is simple and is similar to the methodology most often used in calculating uncertainty in ecological risk assessment.

In this technical note, the product of the ESI and the corresponding EDYS accuracy will be termed a “solution,” e.g., a 70 percent solution. Four EDYS-L scenarios were simulated, each progressively requiring an increase in the site-specific ecological knowledge associated with the EDYS-L application. EDYS-L1 corresponds to the application of one community type for the entire landscape and it represents the simplest application of EDYS-L. In EDYS-L2, multiple EDYS-L community types were applied, but only using the default values within EDYS-L. New species were added in EDYS-L3, these being the two dominant species at the site. EDYS-L4 was similar to EDYS-L3 except that the more complex spatial distribution patterns of the vegetation were accounted for.

Each of these four EDYS-L scenarios resulted in different solution levels when their corresponding ESI were multiplied by the 90-95 percent accuracy level for EDYS in simulating total aboveground biomass (Table 18). The simplest EDYS-L application (EDYS-L1) produced a respectable 65 percent solution, which is good for a screening-level model. The only slightly more complex application, applying multiple EDYS-L community types, produced a very good 85 percent solution. However, neither of these applications could be used to investigate changes in dominant species of the site because these two species are not included in the basic EDYS-L menu. Adding these species reduced the overall simulation accuracy to an 80 percent solution, but provided an 85 percent solution for simulating Ashe juniper and a 65 percent solution for live oak.

Table 18. Solution[1] (i.e., confidence) levels associated with four EDYS-L scenarios as applied to vegetation at the Honey Creek Research Watershed, Texas (second year of the simulations).

EDYS-L Scenario	Total Aboveground Biomass	Ashe Juniper Biomass	Live Oak Biomass
1 One community type	62-66%	NA	NA
2 Five community types	85-89%	NA	NA
3 Two dominants added	79-84%	85-89%	63-67%
4 Spatial mosaic added	75-79%	78-83%	74-78%

[1] Solution = (EDYS Similarity Index) (EDYS Accuracy)

The accuracy of the two most basic EDYS-L simulations decreased over time, but continued to provide 60-80 percent solutions for total aboveground biomass after 10 years. The accuracy of the two more complex EDYS-L simulations (two dominants added, spatial mosaic added) increased over time, providing 85-95 percent solutions of total aboveground biomass after 10 years. Adjusting the initial biomass inputs for the EDYS-L community types to match site-specific conditions resulted in very accurate simulations (95 percent ESI), even using the simplest EDYS-L application (i.e., one community type).

Hydrologic Dynamics. EDYS-L was less accurate at simulating ET and runoff than it was in simulating vegetation dynamics. Similarities to EDYS results for simulating ET ranged from 41 percent for the most simple EDYS-L application (one community type) to 65 percent for the most complex (spatial mosaic added). Although these ESI values were lower than those for the vegetation variables, they still provided useful screening-level results. EDYS had an 89 percent accuracy in simulating ET at Honey Creek (McLendon and Coldren 2005). Multiplying this by the range in ESI for EDYS-L results in 36-58 percent solutions for ET, at the end of two years. The ability of EDYS-L to accurately simulate ET dynamics at Honey Creek decreased over time and modifying the initial biomass values had little effect on the EDYS-L results.

EDYS-L was less useful in simulating runoff than in simulating ET. Compared to EDYS, the EDYS-L results had a similarity of 19-28 percent for the second year of the simulation. EDYS-L 10-year runoff values had about the same accuracy as the 2-year values and modifying the initial biomass values improved the 2-year values only slightly.

A major reason for the lower performance of EDYS-L in simulating ET and runoff is most certainly related to the soil used as the default in EDYS-L. The soil associated with the Plains Montane type in EDYS-L is twice as deep (810 mm) as the Comfort-Rock Outcrop series (425 mm) which forms the major soil type on the Honey Creek watershed. The deeper soil in EDYS-L would hold more soil moisture, thereby increasing ET because of more soil moisture for plants to extract as ET and lower runoff because more moisture could be held in the soil prior to saturation.

Overall Conclusions. EDYS-L, at least as it was applied to the Honey Creek Watershed, provides an excellent screening-level ecological model for vegetation dynamics, a fair model for ET, and a poor model for runoff. Very simple applications of EDYS-L, involving only one community type, are likely to provide 65 percent solutions for simulating total aboveground biomass dynamics. Only slightly more complex applications, involving the application of the most-appropriate EDYS-L community-type to the site-specific types, will likely provide 85 percent solutions. This second level of application would require some type of spatial and vegetation correlation on the order of woodlands, shrublands, grasslands, and wetlands. The ability of EDYS-L to simulate hydrologic dynamics can likely be improved by either further refinements in EDYS-L or linking EDYS-L to existing hydrologic models.

RECOMMENDATIONS. Based on the results of this study, we make four recommendations.

1. **Expand EDYS-L from the present three regions to eight regions.** The results of this study indicate that EDYS-L provides a useful screening-level model for vegetation dynamics. The three regions currently included cover the United States from the Central Plains to the Sierra Nevada mountains. Five additional regions will be required to provide nation-wide coverage: Southeast, Northeast, Midwest, Alaska, and Pacific.

2. **Conduct additional tests of accuracy.** The results of this study are based on one validation study. Validation data are available for nine other sites (Fort Hood, Texas; Fort Bliss, Texas; Big Bend NP, Texas; Fort Carson, Colorado; Piceance Basin, Colorado; Rocky Mountain NP, Colorado; U.S. Air Force Academy, Colorado; Lake Mead NRA, Nevada; Yakima TA, Washington). The vegetation of these locations includes most of the major vegetation types of the western United States, exclusive of the Pacific Coast. Comparing EDYS-L, EDYS, and measured values at these sites would provide a comprehensive evaluation of the capabilities of EDYS-L to simulate vegetation dynamics. Results from these comparisons would enhance understanding of the capabilities and limitations of EDYS-L and determine if the 65-85 percent solutions indicated by the Honey Creek application are general for the model or unique to this one site.

3. **Develop a GIS-capability for EDYS-L.** The results of this study indicate that the simulation accuracy of EDYS-L can be increased substantially by including basic spatial distribution patterns for the vegetation of an application site. The ability of a user to access spatial data and apply these data to an EDYS-L application would be greatly increased if a GIS/EDYS-L linkage existed.

4. **Evaluate an intermediate version of EDYS/EDYS-L.** Numerous validation studies have shown EDYS to be 90-95 percent accurate in simulating vegetation dynamics and 90 percent

accurate in simulating hydrologic dynamics, but the use of EDYS requires a relatively high level of training and extensive site-specific data inputs. EDYS-L requires relatively low levels of training and little additional data inputs, and this present study has shown EDYS-L to provide 65-85 percent solutions for coarse-scale vegetation dynamics but only 20-60 percent solutions for hydrologic dynamics. It seems logical that an intermediate version of the EDYS family of ecological models would be useful. This intermediate version, EDYS-M, would require only slightly more training for its use than for EDYS-L but would contain additional databases, thereby allowing for more accurate and realistic applications than are possible with EDYS-L.

The author also recommends that an EDYS-M version be developed for one sub-region of the United States. The sub-regions selected would be one for which a substantial amount of EDYS data are available and EDYS versions are currently available (e.g., South Texas or the Edwards Plateau of Texas, or the western slope of Colorado). Comparisons would be made among EDYS, EDYS-M, and EDYS-L for this sub-region. These comparisons would provide the information required to evaluate the cost-effectiveness of the three models. Based on these analyses, priorities could be established for developing additional EDYS-M models for other sub-regions of the United States, or continuing to rely only on EDYS and EDYS-L.

SUMMARY: EDYS is a general ecosystem simulation model that has been widely applied in the United States and internationally, and is part of the USACE SWWRP family of models. A number of validation studies have shown it to be 90-95 percent accurate in simulating vegetation dynamics and 90 percent accurate in simulating hydrologic dynamics. Although highly accurate and very robust, EDYS requires a high degree of training in its operation and the application to new sites may require additional input data. Consequently, the U.S. Army Corps of Engineers (USACE) is interested in the development of a simplified version of EDYS (EDYS-L) that can be used in conjunction with EDYS. EDYS-L would be used as a screening-level ecological model and EDYS would be used when highly accurate results are required. A prototype version of EDYS-L has been developed and demonstrated to the USACE districts and other agencies. The next step in the development process is to determine the accuracy of EDYS-L in comparison to EDYS. To do so, both models were applied to the Honey Creek Research Watershed in Texas and their respective outputs compared.

Four levels of EDYS-L, varying in the amount of user inputs required, were used in this study. The most basic level (EDYS-L1) required that only one EDYS-L community type be selected as most representative of the study site and EDYS-L then applied this community to the entire landscape. In the second level (EDYS-L2), multiple (five) community types were applied to the landscape. The third level (EDYS-L3) added two additional plant species to the EDYS-L menu, which were the two dominant species at the site. The fourth level (EDYS-L4) was similar to EDYS-L3 except that it accounted for spatial heterogeneity in the vegetation. Simulations were run, along with those for EDYS, for 2 years and for 10 years and both vegetation and hydrologic outputs were compared.

Based on these comparisons for the Honey Creek Watershed, EDYS-L proved to be a useful screening-level ecological model, especially for simulating vegetation dynamics. When applied at its coarsest scale (EDYS-L1), EDYS-L provided a 65 percent solution when simulating total aboveground plant biomass. This level of application only requires the user to select which

region of the United States the study site is located in and which of five topographic types the site most closely corresponds to. At the second level of application (EDYS-L2), requiring the user to apply multiple community types (e.g., woodland, shrubland, grassland, wetland) to the site, EDYS-L provided an 85 percent solution for total aboveground plant biomass. Adding the dominant two plant species and more detailed spatial heterogeneity did not increase the accuracy in simulating total aboveground plant biomass at 2 years, but did after 10 years, and also allowed for the simulation of the dynamics of the two dominant species. Under these scenarios (EDYS-L3 and EDYS-L4), EDYS-L produced 65-90 percent solutions for these two species. The accuracy of the two most basic EDYS-L simulations decreased over time, but continued to provide 60-80 percent solutions for total aboveground biomass after 10 years.

EDYS-L was less accurate at simulating ET and runoff than it was in simulating vegetation dynamics, in large part because of a poor fit between the soil used in EDYS-L and the primary soil found at the Honey Creek site. Similarities to results from EDYS in simulating ET ranged from 41 percent for the most simple EDYS-L application (one community type) to 65 percent for the most complex (spatial mosaic added). Although these values were lower than those for the vegetation variables, EDYS-L still provided useful screening-level results for ET. EDYS-L was less useful in simulating runoff, providing a similarity to EDYS results of 19-28 percent for the second year of the simulation.

EDYS-L, at least for the Honey Creek Watershed, provided an excellent screening-level ecological model for vegetation dynamics, a fair model for ET, and a poor model for runoff. Very simple applications of EDYS-L, involving only one community type, provided 65 percent solutions for simulating total aboveground biomass dynamics. Only slightly more complex applications, involving the application of the most appropriate EDYS-L community type to the site-specific types, provided 85 percent solutions. The ability of EDYS-L to simulate hydrologic dynamics can likely be improved by either further refinements in EDYS-L or linking EDYS-L to existing hydrologic models.

Based on the results of this study, four recommendations are made. These are: 1) expand EDYS-L from the present three regions to eight regions in order to be applicable to the entire United States, 2) conduct additional accuracy tests using existing EDYS data sets, 3) develop a GIS-capability for EDYS-L to allow spatial data to be efficiently entered, and 4) evaluate the potential of an intermediate version of EDYS/EDYS-L.

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> McLendon, T., C. L. Coldren, and D. L. Price. 2009. *Comparison of results from the EDYS and EDYS-L ecological simulation models as applied to vegetation and hydrological dynamics on the Honey Creek Watershed, Texas*. SWWRP Technical Notes Collection. ERDC TN-SWWRP-09-7. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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